Dosimetric Impact of Aperture-Restricted VMAT on Heart Dose in Breast/CW Cancer Treated with Regional Nodal Irradiation

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INTRODUCTION

Background

- Comprehensive irradiation of the breast or chest wall (CW), including ipsilateral regional nodal irradiation (RNI), is routinely used for selected high-risk patients, particularly those with node-positive disease.
- While VMAT improves target coverage for complex anatomy, it may increase low-dose exposure to heart, particularly for left-sided patients.
- Higher mean heart dose increases risk of major cardiac events (~7.4% per Gy) with no clear safe threshold (Darby et al.).

Purpose

This study compares a proposed aperture-restricted geometry with open-field geometry in VMAT to evaluate cardiac sparing and overall plan quality across convergence modes on three linac platforms.

METHODS

Patient Cohort

- 14 patients: left-sided breast/CW with RNI

Planning Approach (Eclipse V16.1)

- Patient-specific optimization templates created and applied across all plans (without user interaction)
- 6X-FFF VMAT, 40.05 Gy in 15 fractions
- Skin flash: 1cm virtual bolus, removed and plan recalculated for final dose
- Plans normalized to PTV V95% = 95%

Study Design

- 14 Patients
- 2 Geometries:
  Open-field vs Aperture-restricted
- 3 Convergence Modes: **Off, On, Extended**
- 3 Linac Platforms:
  TrueBeam, Halcyon, Versa HD
- 18 Plans/patient → 252 total plans

Field Geometry

- Open-field VMAT: allow to fully encompass target volumes
- Aperture-restricted VMAT: deep tangential field edge limited (~1–2 cm) toward isocenter; restriction achieved via X-jaws (TrueBeam) or MLC limits (Halcyon, Versa HD)

- Identical arc geometry maintained across all plans

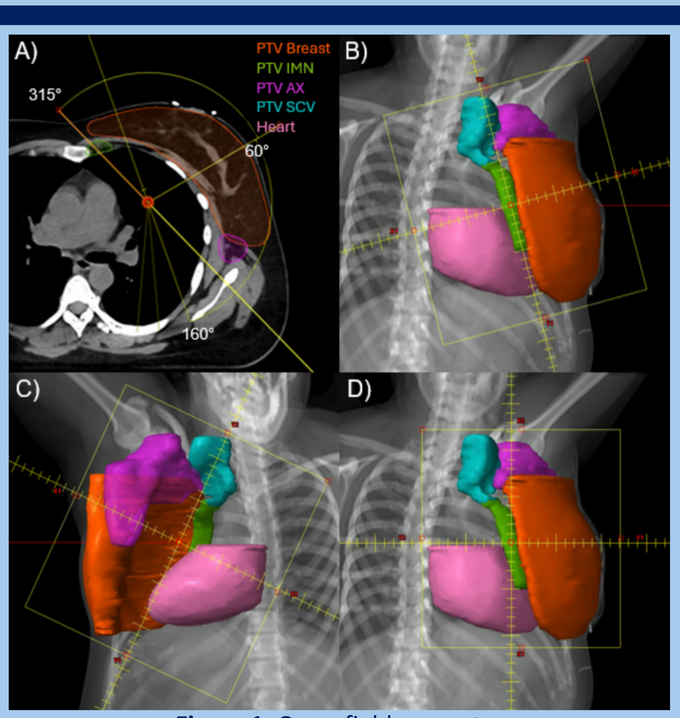

Figure 1. Open-field geometry

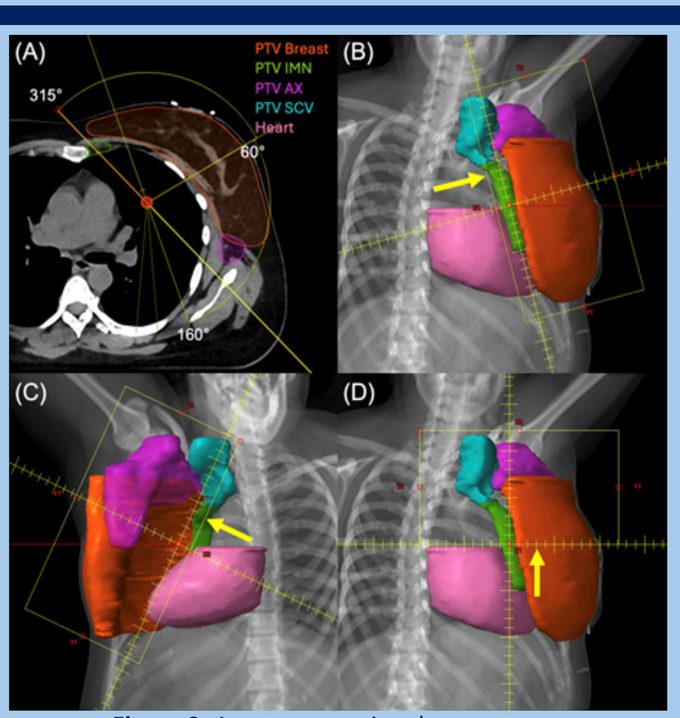

Figure 2. Aperture-restricted geometry

- The isocenter is placed at the midpoint of the superior–inferior extent of the target and shifted posteriorly along the tangential beam path into ipsilateral lung.
- Arcs 1-4: split-arc at gantry of 50°–60° for collimator flipping to maintain a field edge (X-direction) predominantly parallel to the CW, favorable for dose sculpting.
- A 5th arc (collimator 90°) improved conformity and added control points when beam entry was limited by the arm or chin.
- Jaw tracking was enabled on TrueBeam and Versa HD for both geometries.

RESULTS

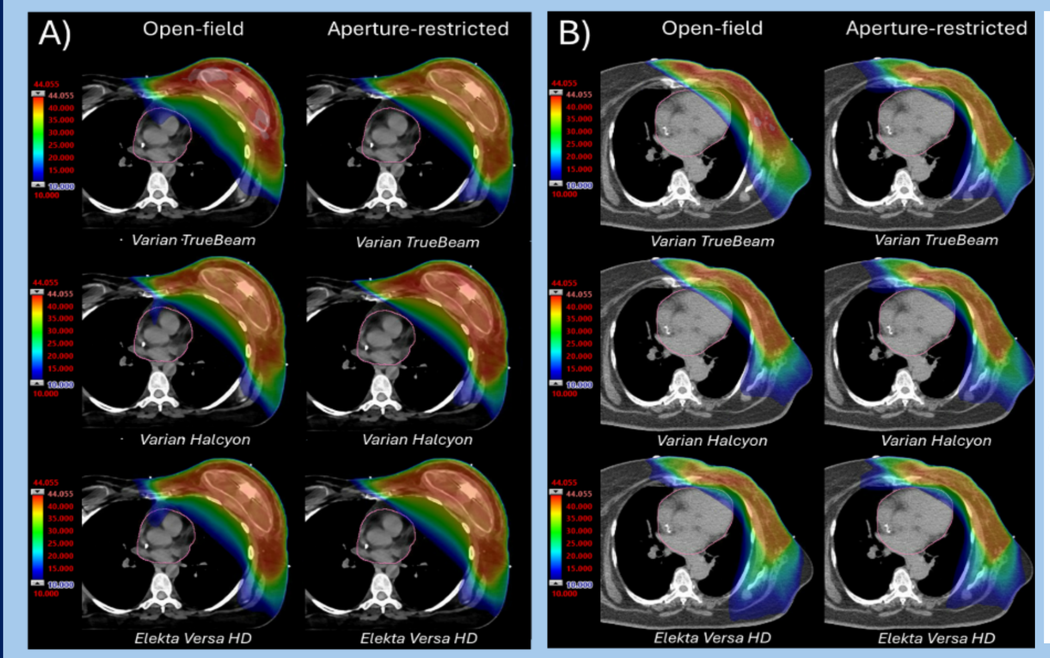

Figure 3. Representative dose distributions (A) tissue expander and (B) chest wall cases.

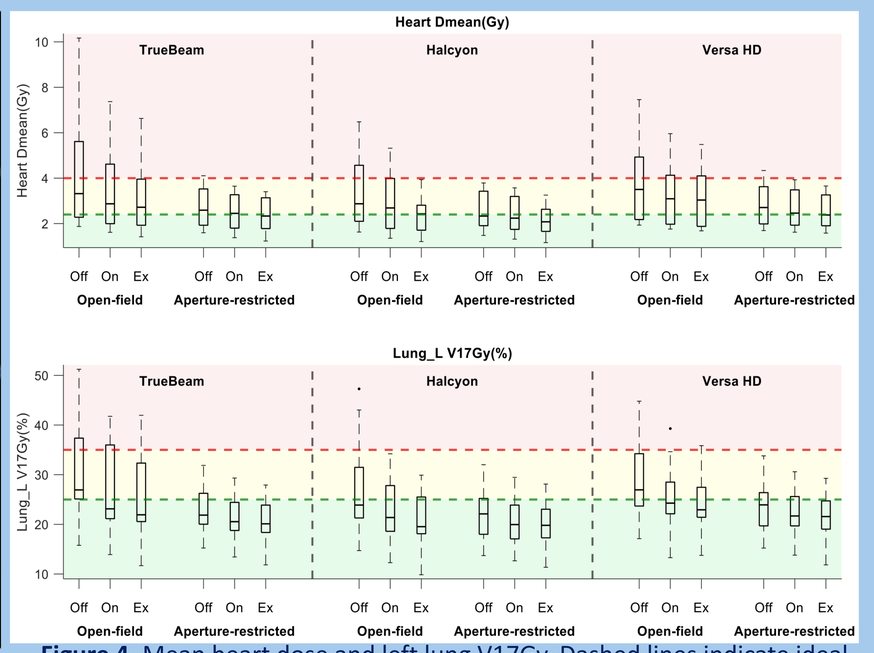

Figure 4. Mean heart dose and left lung V17Gy. Dashed lines indicate ideal and acceptable dose constraints per guideline

- **Aperture-restricted VMAT improved cardiac sparing while maintaining coverage.**
- Extensive convergence modes improved plan quality with increased optimization time (using template, "Off": 6 min, "On": 18 min, "Extended": 50 mins)

Heart Dose

- Mean heart dose significantly reduced with aperture-restricted VMAT
  - > 4 Gy: 26.2% (33/126, open-field) → 2.4% (3/126, aperture-restricted; all *Convergence Off*)
  - Example (using "Off" convergence mode): TrueBeam 4.20→2.71 Gy; Halcyon 3.32→2.58 Gy; Versa HD 3.97→2.84 Gy

Left Lung

- V17Gy reduced with aperture-restricted geometry

Additional Findings

- No significant increase in contralateral lung V4Gy
- Increased contralateral breast/CW V5Gy (dosimetric trade-off)
- Increased MUs with aperture-restricted plans; passed QA
- Comparable delivery time on TrueBeam and Versa HD, with increased time on Halcyon; split-arc: feasible for breath-hold treatments
- Improved quality and reduced hotspot with more restrictive convergence modes

CONCLUSIONS

- Aperture-restricted beam geometry significantly reduces mean heart dose and ipsilateral lung dose while preserving target coverage in VMAT planning for breast/CW irradiation with RNI.
- More extensive convergence modes improved plan quality.
- Prospective clinical implementation testing and evaluation are warranted to validate these findings further.

REFERENCES